Increasing conspicuity on night-time roads: perspectives from cyclists and runners

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Abstract

Pedestrians and cyclists are at significant risk of being killed as a result of a collision with a vehicle at night-time because of their poor conspicuity. Retroreflective strips positioned on the moveable joints, in a biological motion configuration (biomotion), greatly enhances the night-time conspicuity of pedestrians and cyclists, but it is not clear how widely this strategy is adopted among those running and cycling under low light levels and at night. This study explored runners' and cyclists' beliefs about their own conspicuity, and the strategies they use to increase their conspicuity and safety under low light levels

Nine focus groups involving 50 participants (mean age =39.5 ± 13.9 years) were held with individuals who ran and/or cycled under low light conditions or at night-time. Participants explored the strategies they used to increase their perceived conspicuity and enhance their personal safety, and the importance they placed on increased visibility to other road users at night. Data were analysed thematically, with two main themes identified. *Strategies* describes the different approaches used to increase their own conspicuity when running or cycling in low light conditions, which include ineffective strategies. *Importance* describes how conspicuity relates to other considerations that influence cyclists and runners. While they may believe that conspicuity is essential for their safety, they may compromise their own conspicuity by prioritising style or comfort, or because they believe that being more conspicuous is of limited value because it cannot compensate for the behaviour of other road users.

In summary, cyclists and pedestrians are largely unaware of effective strategies to increase their night-time conspicuity, particularly the use of biomotion reflective strips. Garment manufacturers should ensure that conspicuity features (with supporting educative product information on labels) are incorporated into cyclists' and runners' clothing or accessories, to improve wearer conspicuity and hence safety in low light conditions.

Keywords: night-time visibility, conspicuity, cyclists, runners, biomotion, clothing

1. Introduction

Pedestrians and cyclists are at significant risk of being injured or killed as a result of a collision with a vehicle at night time (Kwan and Mapstone 2004), because of their poor conspicuity (Owens and Sivak 1996). Crashes between vehicles and pedestrians are over-represented at night, with pedestrians being 3-7 times more likely to be involved in a fatal collision at night than in the day (Sullivan and Flannagan 2002). Even though exposure rates for cycling are much lower at night than in the day, data from a range of countries indicate that cyclist fatality rates at night are high (Jaermark, Gregersen et al. 1991; Henley and Harrison 2009). The risk of injuries at night is also two times higher at night than in the day, and for rural areas the injury risk is five times higher (Johansson, Wanvik et al. 2009; Twisk and Reurings 2013).

During the daytime, fluorescent materials are effective in increasing conspicuity (Kwan and Mapstone, 2009) and can reduce collisions (Lahrmann et al., 2018), while at night, lights and retroreflective materials are more effective (Kwan and Mapstone, 2009). Retroreflective material can enhance the nighttime conspicuity of cyclist, walkers and runners and there has been some debate regarding where this retroreflective material should be placed in order to achieve optimal conspicuity. When retroreflective materials are positioned on the major movable joints, this creates a sense of "biological motion" or "biomotion", i.e. the viewer perceives the lights as moving body parts on a person or animal (Johansson 1975; Tyrrell, Wood et al. 2016). The visual system is extremely sensitive to biological motion and this ability allows information, such as whether a moving person is present and the characteristics of their movements, to be extracted from the motion of tiny point lights located on the major joints (Johansson 1975). When retroreflective strips are placed on the movable joints and are lit up in the oncoming headlight beam they produce a sense of biological motion that enhances drivers' ability to recognise pedestrians from a safe distance at nighttime, resulting in a 20 times increase in the distance at which a pedestrian or cyclist is first recognised (Wood, Tyrrell et al. 2005).

This research on the benefits of biological motion has resulted in a change to the Australian and New Zealand standard for high-visibility clothing for night-time road workers (King and Wood 2013), yet there has been no translation to other groups that use road systems at night. This is despite there being a large number of people who walk, run or cycle on our roads at night-time, either for commuting or exercise. There are likely to be many more individuals

who do not undertake these activities because of concerns regarding their safety (Daley, Rissel et al. 2007). Indeed, concerns about conspicuity mean that parents drive their children to school rather than allow them to cycle (Ghekiere, Van Cauwenberg et al. 2014), with parental constraints on physical activity extending beyond active transport to reducing the amount of physical activity that children undertake outside of school (Carver, Timperio et al. 2010). This is of particular concern given the link between low levels of physical activity, obesity and consequent morbidities. A recent meta-analysis demonstrated that active commuting such as walking, running or cycling can be associated with an 11% decrease in risk of cardiovascular disease (Hamer and Chida 2008); other implications include reductions in traffic congestion and vehicle emissions.

Studies have also shown that there is a lack of clarity among vulnerable road users regarding the conspicuity effects of different materials, such as florescent and retroreflective materials (Wood, Tyrrell et al. 2013). Fluorescent materials convert invisible ultraviolet light in natural daylight to visible light (Joint Technical Committee 1999) and so increase conspicuity only under daytime conditions, whereas retroreflective materials reflect light such as headlights back towards the light source so are more effective in low light conditions (Wood et al., 2013). People are also often resistant to wearing clothing that has a safety focus because it lacks aesthetic appeal or is perceived to be cumbersome or uncomfortable. Clear examples of these concerns about style and comfort are reluctance to wear cycle helmets because of a belief that they are unattractive (Lajunen 2016), or because they are uncomfortable (Hollenberg 2018). Similar considerations are likely to affect willingness to wear other clothing and accessories. In addition, research has demonstrated that despite cyclists being generally well informed regarding the importance of wearing high-visibility clothing and the benefits of conspicuity aids, they frequently do not use these aids (Hagel, Lamy et al. 2007).

This study aimed to better understand the strategies that cyclists and runners use to increase their conspicuity and safety at nighttime and the relative importance that they place on increased conspicuity to other road users at night, both in terms of perceptions, and their choices of exercise clothing and associated apparel accessories at night.

2. Methodology

A primarily qualitative methodology was employed, comprising a series of focus groups conducted in three countries. Participants were also asked to complete quantitative rating scales.

2.1 Participants

In total there were 50 participants (mean age =39.5 ± 14.0 years, 20 female, 30 male); 34 from Brisbane (Australia) and 16 from Leeds (United Kingdom). These cities provide locations that differ in respect to their climate and the extent to which residents cycle for commuting and leisure purposes. Participants were adults who ran/cycled on the roads in low light conditions, lived or worked locally in each city and were recruited through advertisements through workplaces, social media groups and through emails to cycling and running groups. Potential participants completed an online recruitment form and were booked to attend a focus group based on their activity type (night-time cyclists or runners or those who undertook both cycling and running at night (mixed)). Three groups were with those who solely or mostly cycled, three with those who solely or mostly ran, and three with those who both cycled and ran. All participants were offered an AU$50 gift voucher for their participation in the focus group.

2.2 Procedure

Nine focus groups were held: six in Brisbane, Australia (two cyclists, two runners, two mixed) and three in Leeds, UK (one cyclist, one runners, one mixed). Focus groups provide a means of gaining an in-depth understanding of a topic or issue in a group setting, where the dynamics of the group lead to participants disclosing and discussing their thoughts, feelings and experiences in a way that they may not do in a one-to-one interview. A semi-structured topic guide was used to initiate and steer the discussion. The term “visibility” was used throughout rather than “conspicuity” as it is easier for participants to understand. Discussions covered:

- Clothing worn when running/cycling under nighttime conditions;
- Choosing clothing for running/cycling;
- Perceptions of participants’ own visibility to motorists at nighttime.

At the Brisbane site, participants in each group were asked to rate the relative importance of visibility versus comfort, and visibility versus style when purchasing clothing, by placing a mark on two separate visual analogue scales (VAS) of 250 mm in length. The first VAS contrasted the importance of visibility versus comfort with three anchor points: visibility as being of sole importance; visibility and comfort being of equal importance; and comfort being of sole importance. The second scale contrasted the importance of visibility versus style, scaled from visibility as being of sole importance; visibility and style being of equal importance; and style being of sole importance. Participants' positions along the VAS were converted to numbers by applying a conversion factor (scale position – 125) x 0.08, such that the anchor points indicating equal importance were set at 0.

Focus groups were led by one of two facilitators (FF, LB), who were either highly experienced in conducting focus groups (FF) or had undergone extensive training in delivering focus groups (LB) and were aided by an assistant, lasted one hour and were audio recorded and transcribed verbatim. The study followed the tenet of the Declaration of Helsinki and ethics committee approval was obtained from Queensland University of Technology. All participants were given a full explanation of the nature of the study, what taking part would involve, and how to withdraw from the research. Written informed consent was obtained.

2.3 Data analysis

Transcripts were analysed thematically using the methods of Braun and Clarke (2006). Transcripts were coded using the research question: "What does conspicuity mean to runners/cyclists?" and referred to the key points covered in the topic guide. An inductive approach was taken in which the codes were generated from the data rather than by applying a pre-determined framework (Braun and Clarke (2019). Two authors (FF, LB) independently coded the transcripts and any differences in coding were discussed and resolved. Codes were grouped together with others of similar meaning and sorted into a thematic structure that best described the data. The criteria for a theme were that it was internally homogeneous, i.e. the sub-themes it contained all shared a certain perspective, and that it was externally heterogeneous, i.e. that the themes were fundamentally different from one another. This stage was iterative, with sub-themes merging and moving between themes until a grouping was identified that provided the most parsimonious data structure while capturing the full set of codes.

3. Results

3.1 Qualitative Results

Two main themes were identified in the data:

- **Strategies** describes the different approaches that people use to try to increase their own conspicuity when running or cycling in low light conditions;
- **Importance** describes how conspicuity relates to other considerations that influence cyclists and runners: while they may believe conspicuity to be essential for their safety, they may compromise their conspicuity by prioritising style or comfort, or because they believe that being more visible is of limited value because it cannot compensate sufficiently for the behaviour of other road users.

These themes are described in detail below and illustrated using quotes from each of the focus groups that were selected on the basis that they best illustrated each sub-theme, and were labelled with the city that the focus group took place (Brisbane or Leeds), the focus group number and the gender of the participant.

1. Strategies

This theme comprises four subthemes that describe what participants do to increase their conspicuity when cycling or running, and how that changes under low light conditions, i.e. at dawn, dusk or at nighttime.

Lights

This sub-theme describes beliefs and experiences regarding using lights to increase conspicuity at night. Cyclists in particular, relied heavily on lights, with many using lights during the daytime as well as under low light conditions. They believed that lights, high lumen LEDs in particular, are the most effective strategy to increase their own conspicuity, and accordingly, many were willing to pay more for higher lumen LED lights because they are brighter. Many participants described using multiple lights, e.g. on the front and rear of their bikes and also on their helmets, as more lights were considered to be superior for gaining motorists' attention.

"I have a 600 lumen light on my handle bars, a 200 lumen tail light and a 300 lumen light on my helmet. If I'm really bright everyone is seeing me from ages away." (FG Brisbane 5, male)

"I have five lights on the back of my bike that I commute on: some flash, some are static. I am literally glowing head to toe." (FG Leeds 3, male)

Some participants (from both Brisbane and Leeds) noted that it is illegal to ride at night without lights, and this increased the perception that lights are the best way to increase conspicuity in low light and darkness. Discussion focused on the relative efficacy of flashing versus constant lights. Some believed that flashing lights decreased conspicuity and others that flashing would attract drivers' attention. Several participants had lights on their helmets and believed that this is useful to increase their conspicuity at a junction where they would look around and at cars as a strategy to increase conspicuity.

Very few participants used lights while running, although most were aware of them and several talked about how clip-on LED lights can be a useful way of increasing conspicuity when running on or near a road. A few talked about using head torches, although this was primarily to increase what they can see, rather increase their own conspicuity to other road users.

Colour

Many participants, including both cyclists and runners, used colour as a strategy to increase their conspicuity and talked about brightly coloured clothing as being very effective at night. Cyclists also talked about the colour of their bike and cycle helmet increasing their conspicuity. While there was discussion around how bright colours are most effective in daylight, some participants had strong beliefs that bright colours would increase conspicuity even in low light and darkness. Light colours were highlighted as being more effective in low light conditions and several participants talked about how they would try to avoid wearing all black in low light.

"I go for bright colours normally because I run home on the roads and people are a bit crazy so I like to be seen especially in the dark." (FG Brisbane 4, male)

"I have a bright orange bike so if they can't see the bike then they're not going to see me." (FG Leeds 1, male)

A few discussed how colour contrast is very important, so bright green would be a good way of increasing conspicuity in a city but not in a rural area with lots of vegetation. There was confusion between bright colours and fluorescent colours. Participants believed that fluorescent clothing is more visible at night but were often not sure whether a clothing item was fluorescent or simply bright.

Retroreflective material

Some participants talked about wearing retroreflective clothing in low light but many had not previously considered this as an effective means of increasing conspicuity. Some suggested that this was because it can be difficult to tell whether a garment is retroreflective. Participants talked about how manufacturers or retailers often don't mention retroreflectivity on garments, which suggests it is not important. Indeed, many talked about how they forget or don't think to check about retroreflectivity when they are buying cycling or running clothing, so that buying clothes with retroreflective material is not a deliberate decision.

"I've bought stuff online and not realised until I got it that it had retroreflective stuff on it." (FG Brisbane 5, female)

Some participants discussed how their running and cycling shoes have retroreflective material on the heels but few had considered the conspicuity benefits. Some talked about retroreflective strips on shoes and clothes being too small to be seen at distance and so therefore not an effective way of increasing conspicuity. There was discussion regarding how some brands have retroreflective detailing on a garment's seams or on a logo and how this suggests that retroreflective strips are a design feature rather than a safety feature. Some were aware of jackets and rucksacks made entirely out of retroreflective material and most firmly believed that increasing the amount of retroreflective material in a garment would increase its conspicuity. Alongside this, some participants were aware of apparel accessories such as socks, gloves and arm bands with retroreflective trimming but wore these items primarily for protection from the weather. Only three participants suggested that retroreflective materials "that move with you", such as ankle bands, are effective. No other participants were aware of

biomotion. Most considered retroreflective strips in clothing as "nice to have" rather than essential.

> *"The shorts that I have actually have a reflective strip on the back; it's something that just came with them. I didn't think about it when I bought them but I guess it is probably good because I run on the roads a lot." (FG Brisbane 3, female)*

Route choice

Participants talked about how they usually choose routes that are brightly lit as a strategy to increase their conspicuity. For runners, however, this often means that they run alongside main roads and so encounter more traffic. They believed this to be safer than running on quiet roads, which might put their personal safety at risk. Some talked about choosing routes with low levels of traffic when they know their conspicuity is low.

> *"As a lady I wouldn't be running while it's dark at night on my own so I'm always running by the side of the road [under street lights]." (FG Leeds 1, female)*

> *"If I go for a ride at night I will try and like, I know I'm wearing dark clothes so like I'll try and use routes that aren't heavily trafficked." (FG Brisbane 1, male)*

2. Importance

This theme describes participants' perceptions of the importance of trying to increase their conspicuity in relation to other considerations. While they believed that conspicuity would increase their safety on the roads, there are tensions, with other considerations that may mean that conspicuity is considered as relatively less important, or that the behaviour of other road users means that it is not as effective as it might be.

Safety

This sub-theme is about how being visible to other road users is essential to stay safe on the roads. While all participants talked about the importance of conspicuity, those who had been involved in a collision, either as a runner or a cyclist, were particularly keen to be conspicuous. Cyclists believed conspicuity to be more important than did runners, although the context of their ride influenced perceptions of the importance of conspicuity, with conspicuity being described as less important when riding in a group. Indeed, participants

talked about the importance of wearing “club kit” on a group ride, which is rarely designed for conspicuity.

> *“I've got dark cycling gear and I'll wear that if I'm in a big group but if I'm by myself I will pick out brighter colours.” (FG Brisbane 5, male)*

In contrast, conspicuity during a commute ride was perceived as being especially important: participants talked about how drivers are less likely to notice a single cyclist, and commuting drivers may be tired or distracted so less likely to actively look out for cyclists.

> *“Commuting seems to be a more dangerous time because people are rushing about trying to get to work in the car. It generally busier and you know people aren't always taking as much time or driving as well as they might do.” (FG Leeds 1, female)*

Runners talked less about conspicuity being important, with many noting that most collisions happen when runners cross the road without looking. However, more concerns about conspicuity were raised by those who run on the road on routes without sidewalks (paved paths for pedestrians at the side of the road). Parents who run or ride with their children were more concerned about their children’s conspicuity than they were about their own.

> *“I just think he [my 10-year-old] needs to be so visible when we run just in case he misses something or someone is flying around the corner. Because sometimes he will just step out and look this way but then someone could just, you know what I mean. I just think it's definitely really important to be really really visible.” (FG Leeds 2, male)*

Tensions

This sub-theme describes factors that reduce the perceived importance of conspicuity. The main issue discussed by cyclists was the attitudes and behaviours of drivers. Many cyclists described drivers failing to notice them, often despite looking directly at them. All cyclists talked about experiencing close passes, and many believed that drivers sometimes do this deliberately.

"I've had so many experiences where I've had drivers looking directly at me and I've got bright flashing lights on the front and they still don't see me." (FG Brisbane 2, female)

"Never trust a motorist because they're not looking out for you. All they want to do is get home after the end of their commute or whatever. They will purposefully cut cyclists up. There are people who will literally park in the gutter to try to stop you from going up the inside because you'll gain a metre." (FG Leeds 3, male)

There was considerable discussion about how driver behaviour sometimes makes it feel that it is pointless for cyclists to try to increase conspicuity. Some participants talked about how they do not agree that the emphasis should be on cyclists or runners making themselves more visible. Instead, it should be up to drivers to actively look for other road users and for authorities to design safer junctions and install more bike paths.

"I think are think there are two possibilities, one is the personal possibility for high visibility I think on the other side there is the responsibility from the government that they are responsible for good visibility, for good lit junctions and especially the point where we have accidents." (FG Brisbane 6, male)

There were several discussions about that drivers tend to be more considerate around cyclists who look less experienced or less safety conscious, so that wearing high visibility clothing that looks more professional could paradoxically put them at greater risk.

"The more you look like a daggy commuter I think the more cars will avoid you." (FG Brisbane 2, male)

"I don't want to look like a cyclist. I want to look like a tradesman who's going somewhere." (FG Brisbane 6, male)

Some of the runners talked about how cyclists on shared paths represent a significant hazard, and how cyclists often have little regard for runners. In the Brisbane groups, electric scooters were also identified as a hazard.

"Cyclists can be a bit more aggressive on shared paths because they're the bigger thing. They'll yell at you to get out of the way and I'm literally like: I've got nowhere to go, so you can literally slow down a bit, wait for a point to go around me." (FG Brisbane 3, female)

"The amount of scooters where I've yelled at people, nearly got taken out and watch them nearly take out me." (Brisbane, 3, Female)

Practicality and Style

Another tension, discussed by both cyclists and runners, was that comfort and durability are more important than conspicuity when buying clothing. Participants discussed how clothing should be appropriately warm or cool, sweat wicking, with a good fit and style. Black was thought to be a practical colour as it does not show dirt or sweat. There were concerns that retroreflective strips would cause chaffing, compromise the fit, would make them overheat, would require the garment to have long sleeves or pants, or mean that the garment can't be washed as often. All of these disadvantages were perceived as being more important than a potential increase in conspicuity.

"When you're buying you don't really think of visibility. It's more the look and the comfort of it." (FG Brisbane 4, male)

Cost was also a consideration, where few participants would be prepared to pay significantly more for clothing that increases their conspicuity. Some participants did not have specific clothes for cycling and wear the clothes they will be working or socialising in, which are not optimised for conspicuity, thus any safety elements would need to be subtle.

"I wouldn't pay more for reflective but I do think it's a good idea. (FG Brisbane 4)

If I thought about it was that it might cost you $40 more for a jersey, it's not a lot to pay to potentially reduce the chance of getting hit." (FG Brisbane 2, male)

Personal Safety

Some runners, particularly female, talked about how they prefer *not* to be visible when they are wearing running clothing. For some, this is because they are embarrassed about their

appearance and they would rather not attract attention to themselves. Others, were concerned that they would be a target for crime when running alone.

> *"I run in busy areas, so well lit like main roads. I don't run on back roads in the dark so during the day I'll do like suburbs but like at night I'll do main roads." (FG Brisbane 4, female)*

> *"I'd prefer to be low visibility in that I'm not noticeable because I'm slow and I do like listening to music when I run so I think that's also a safety thing. So I think actually I'm all in black no one is going to see me."(FG Brisbane, 1, female)*

3.2 Quantitative Results

Our small group of participants rated both comfort (M = -3.47, SD = 3.51) and style (M = -2.03, SD = 4.52) as relatively more important than visibility. A one-way between subjects ANOVA was conducted to compare the effect of group membership (cyclist, runner or mixed) on the importance of visibility when compared with comfort and style. There was a significant effect of group membership for the comfort vs. visibility ratings ($F(2,32) = 5.88$, $p = .007$) (Figure 1). Post hoc comparisons using the Tukey HSD test revealed no significant differences between the mixed groups (M = -3.16, SD = 3.89) and the runners and cyclists groups. However, the mean score for runners (M = -5.79, SD = 3.26) was significantly lower than cyclists (M = -1.58, SD = 2.10); $p = .005$. While all groups were more concerned about comfort, runners are more concerned about comfort and less concerned about style than cyclists.

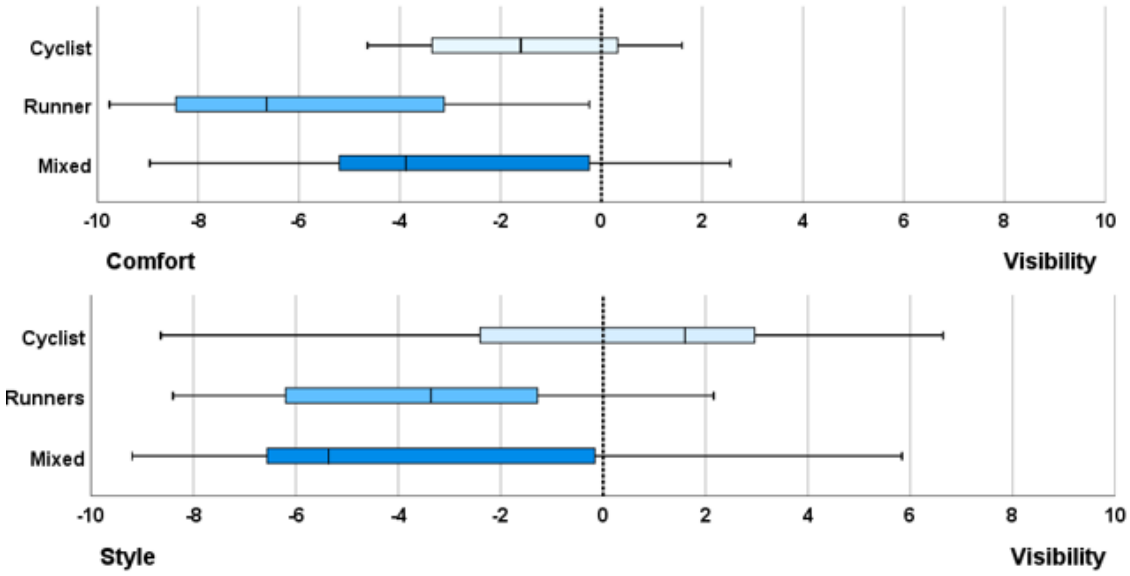

Figure 1. Boxplots of participants' ranking of the importance of visibility compared to comfort and style, when purchasing sports clothing for the Cyclists, Runners and Mixed (both a runner and cyclist) groups.

There was also a significant effect of group membership for visibility vs. style ($F(42,32) = 4.19$, $p = .024$) (Figure 1). Post hoc comparisons revealed no significant differences between the mixed groups ($M = -3.51$, $SD = 4.83$) and the runners and cyclists groups. However, the mean score for runners ($M = -3.67$, $SD = 3.18$) was significantly lower than for cyclists ($M = 0.60$, $SD = 4.36$); $p = .039$, indicating that cyclists rate visibility as more important than style relative to the runners.

4. Discussion

We explored perceptions of conspicuity under low light conditions for cyclists and runners. Two main themes were identified in the focus groups: Strategies and Importance. The first theme, *Strategies,* describes what cyclists and runners do to increase their conspicuity under low light conditions i.e. dawn, dusk or nighttime. This theme incorporated four subthemes of Lights, Colour, Retroreflective Material and Route Choice. The second theme, *Importance*, revealed participant's perceptions of the importance of trying to increase their conspicuity in relation to other considerations. This theme also incorporated four subthemes of Safety, Tensions, Practicality and Style and Personal Safety.

Overall, the results demonstrate that there was a belief that lights are the most effective way to increase conspicuity, with cyclists relying heavily on bicycle lights in order to be seen. There was considerable discussion about the relative efficacy of flashing versus constant or static bicycle lights. Some participants believed that flashing lights decreased conspicuity, whereas others thought that flashing increased conspicuity through attracting drivers' attention. Survey-based research indicates that bicycle lights are rated as being more visible to drivers by participants who are cyclists, than by participants who are drivers themselves, particularly at night (Wood, Lacherez et al. 2009). Indeed, a bicycle light, whether static *or* flashing, did not improve drivers' ability to recognise that a cyclist was present on the road ahead in studies undertaken on a closed road circuit (that is free of other traffic) at night-time (Wood, Tyrrell et al. 2012). There was also no discussion in the focus groups of the fact that lights provide drivers with only limited distance cues, so they cannot identify how far away a cyclist or runner is. Indeed, research has demonstrated that a tri-light formation can provide cues regarding approach speeds under low light conditions (Gould et al., 2012). Thus while bicycle lights may alert drivers that there is something on the road ahead, it does not allow them to recognise that it is a cyclist or runner, nor their distance away.

Many participants discussed how they relied on colour to increase their conspicuity at night and believed that brightly coloured clothing and fluorescent clothing is effective, even under low light conditions. This finding is consistent with previous survey results (Wood, Lacherez et al. 2009), and quantitative research on a driving circuit (Wood, Tyrrell et al. 2013), that also found that cyclists overestimate the effectiveness of fluorescent clothing at night. Additionally, participants favoured having colour on their bike or helmet to increase conspicuity. It has been suggested that one potential reason for this preference might be the Helmholtz-Kohlraush effect, where intense saturation of the spectral hue is perceived as part of the colour's luminance, hence people believe that bright colours will increase conspicuity. However, research has demonstrated that the Helmholtz effect diminishes when ambient illumination is low (Ikeda and Ashizawa 1991; Stalmeier and de Weert 1994; Sayer, Mefford et al. 1998; Sayer, Mefford et al. 1999).

One of the most important elements identified from the focus groups was that few participants acknowledged the importance of retroreflective clothing in low light conditions. The majority had not considered retroreflective material as being an effective means of increasing conspicuity. Furthermore, there was a clear consensus among participants that a

larger surface area of retroreflective material increases conspicuity and there was discussion of the benefits of jackets and rucksacks made entirely out of retroreflective material. This finding is consistent with previous research which identified that cyclists rated wearing a retroreflective vest as being more effective for increasing conspicuity over and above the use of retroreflective strips worn on the moveable joints (Wood, Lacherez et al. 2009). However, retroreflective vests have been demonstrated to be significantly less effective for increasing conspicuity, as a high concentration of retroreflective material is limited to the torso, subsequently delivering less motion information to approaching motorists (Wood, Tyrrell et al. 2013). In contrast, wearing retroreflective strips on the moveable joints creates the effect of biomotion, where a driver can actually recognise that a human is present, rather than misinterpreting the illuminance for a sign or a boulder. In one closed road study conducted under low-beam headlight conditions, drivers recognised the presence of a pedestrian at a distance that was more than 20 times further away when the pedestrians wore clothing incorporating retroreflective material in a biomotion configuration, as compared to wearing black clothing (148 m vs 6 m respectively) (Wood, Tyrrell et al. 2005).

Other interesting findings included that the selection of more brightly lit running routes in order to try and increase their conspicuity for a few participants. However, this often meant that they run alongside main roads, which exposes them to more traffic.

All participants talked about the importance of conspicuity, however, those who had been involved in a collision, either as a runner or cyclist, were more motivated to be conspicuous. While these perceptions of the importance of conspicuity are encouraging, individuals should not have to experience a potentially fatal crash in order to recognise these concepts. Moreover, cyclists believed that conspicuity whilst commuting is essential, as drivers may be tired or distracted and less likely to actively look out for other road users. However, a number of cyclists noted that when riding in a group, the emphasis on the importance of conspicuity decreases. This finding supports previous research that investigated the differences in safety perceptions between cyclists and drivers. Indeed, research has indicated that cyclists rate riding in a pack to be significantly safer than drivers' perceptions of cyclists safety when riding in a pack (King, Wood et al. 2012). These authors concluded that one's self-identification as a cyclist is associated with interpreting one's cycling behaviour as being safer than drivers consider it to be. This can be linked to the idea of a 'pack mentality' and the misperception of 'safety in numbers' when cyclists ride in groups. When riding in a

group, cyclists may become less aware of their surroundings and less concerned for safety compared to when cycling alone, where they are solely responsible for looking out for motorists. This can be linked to the social psychology phenomenon of Social Loafing, where there is a tendency for individuals to expend less effort when working collectively compared to when working individually (Karau and Williams 1993).

Additionally, runners commented that the majority of collisions occur when runners cross the road without looking. Therefore, runners who had to interact with roads or motorists at some point in their run were more concerned about conspicuity than runners who solely run on off-road paths. In terms of research evidence, there are no available statistics regarding the number of pedestrian casualties that occur while undertaking exercise such as running at the time of their collision with a vehicle. However, there are numerous anecdotal accounts in the media regarding the number of runners killed or injured at night-time and the fact that that these incidents commonly occur when runners are crossing the road.

Numerous discussions explored the tensions between cyclists and drivers, with cyclists noting that drivers often fail to notice them, even when directly looking at them. This phenomenon has been termed "looked-but-failed-to-see" (Herslund and Jorgensen 2003), where drivers fail to detect a cyclist in time to prevent the crash, even though they report that they had correctly looked in the direction of the cyclist. This late (or non) detection of cyclists highlights that lack of conspicuity may be a critical contributing factor to their crash involvement (Lacherez, Wood et al. 2013), however, it also confirms cyclists' beliefs that regardless of what they wear, drivers may fail to see them. Indeed, many of the cyclists that participated in the focus groups believed that drivers deliberately pass close to cyclists to unnerve them and this antisocial behaviour leads cyclists to believe that increasing conspicuity is pointless. Interestingly, some cyclists believed that motorists give more room to cyclists who look more 'inexperienced' when overtaking than those who dress in sports clothing, although there is evidence that this does not occur in practice (Walker, Garrard et al. 2014; Debnath, Haworth et al. 2018). Furthermore, many participants suggested that emphasis should not be placed on cyclists and runners to make themselves more visible, but that drivers should actively look out for other road users and government authorities should design safer junctions and increase the amount of bike paths.

It was clear across all groups, that the practicalities of the garment outweigh the importance of conspicuity. The consensus was that it does not matter how visible the garment is: if it is not comfortable, no one will wear it. Conspicuity was almost unanimously considered to be an added benefit rather than a core criterion when choosing exercise clothing. A quantitative approach allowed us to identify which group of road users (runners, cyclists or mixed) are more likely to prefer clothing that offers comfort or style over visibility. While these results are based only on a small sample they demonstrate that both cyclists and runners believe comfort to be more important than visibility. Runners also rated style as more important than visibility. Overall, cyclists rated visibility as slightly more important than style, although there was a wide variation in responses. This is perhaps because cyclists, by nature of spending more time on roads and in traffic than runners, have more exposure to drivers and therefore are more aware of their vulnerability. However, there are many more pedestrians than cyclists, with the World Health Organisation (WHO) estimating that pedestrians account of 22% of all road deaths internationally, with more than 270,000 pedestrian's fatalities per annum (World Health Organisation 2013). Therefore, it is imperative that while advertising needs to be aimed at both cyclists and runners, it is the latter, as well as pedestrians who commonly walk on roads under low light conditions, that need most convincing. Additionally, aspects such as cost and durability were raised at being important factors that play into purchasing behaviour. Concerns regarding whether retroreflective strips would decrease the durability of a garment were also raised.

An interesting and unexpected finding was the perception of personal safety and conspicuity in low light conditions. Some runners, particularly female runners, expressed the desire to be *invisible* at night when running alone because of the threat of being attacked and so preferred to wear black. Moreover, they talked about feeling safer running next to a busy main road than a road with less traffic. This concept is particularly concerning, as women identified that they wore black to be invisible to potential attackers yet also run next to a busy main road. While main roads may provide the illusion of safety, this is paradoxical, as motorists typically fail to see runners wearing black, thus increasing the risk of a collision on busy roads (Tyrrell et al., 2016).

While the risk of actually being attacked when running is relatively low, a survey of 2,533 women revealed that 58% of women under 30 were subjected to harassment whilst running (Kita and Smith 2017). It seems that for many female runners, being invisible for personal

safety reasons outweighs the importance of being visible to oncoming traffic. This is a relevant and pertinent finding that must be explored in future research, in order to evaluate how women can increase their visibility to motorists without compromising their personal safety, and also the role of road lighting in enhancing perceptions of personal safety (Fotios, Unwin et al. 2015). This, however, would be a short-term strategy as in the long term, interventions need to be directed towards the perpetrators in order to change their behaviour and prevent harassment and crime against women in general.

4.1. Strengths and limitations

The strength of the study was in recruiting participants with a wide range of running and cycling experiences under low light levels and at nighttime from two cities that differ in both climate and cycling uptake. We also included cyclists who commute and also those who cycle only for leisure. However, as with all qualitative studies, there are limitations based on the number of participants. Although nine focus groups is relatively large for a qualitative study, our results are nevertheless based only on 50 people. While the discussions reached saturation (i.e. no further new findings) before the final group, which provided confidence that the results were based on a sufficiently diverse range of experiences, the study is limited in the extent to which it can be generalised to other cities. The small sample size also affects the generalisability of the quantitative findings, and further research with larger, population-based sampling would be useful to further examine the trade-offs between comfort, style, and conspicuity.

4.2 Conclusions

In conclusion, we found that cyclists and runners are largely unaware of effective strategies to increase their night-time conspicuity. Importantly, few participants acknowledged the importance of retroreflective clothing in low light conditions, particularly the use of retroreflective strips in the biomotion configuration. In addition, despite being aware of the importance of conspicuity for their safety under low light levels and at night, participants tended to prioritise style or comfort over conspicuity.

4.3. Future Directions

The lack of recognition of the biomotion effect suggests that future research needs to explore cyclists' and runners' attitudes towards garments which incorporate the biomotion configuration and what would motivate them to wear these garments. Additionally, this study highlighted that more research is needed regarding women's safety at night and how the balance between being visible to motorists and being invisible to potential threats needs to be navigated. Further research is also warranted around climatic variations, where the use of retroreflective biomotion features are restricted for short-sleeved tops and short pants which are often preferred in warm weather. In addition, further research is needed on supporting garment labelling or product information to better enhance consumer knowledge, with the consequential likelihood of increased uptake (purchase) of exercise clothing that increases safety in low light conditions.

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